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METEOROLOGICAL OFFICE
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A Drying Power Nomogram

A nomogram has been produced to estimate the daily drying power of the atmosphere using day of year, mean cloud amount, wind speed, temperature and dew point depression as input parameters. The output in millimeters represents the evaporation from a freely transpiring, crop covered surface during the daytime period.

The evaporation is the sum of the radiation and aerodynamic terms.

1. The Radiation Term.

The basic equation is $R_{n(h)} = \frac{1-\alpha}{1+\beta} S.F_1 \sin\Theta - L_o F_2$ (Monteith and Szeicz 1961) (1)

R_n the net direct solar radiation available for evaporation.

α the albedo, representitive of a short, growing crop (= 0.25)

β the heating coefficient ($\simeq$ 0.1) which was introduced to allow for increasing upward long wave radiation during the day due to surface heating.

S the solar constant (1396 Wm-2)

Lo a long wave radiation term for clear skies, taken to be 60 Wm-2 by day.

$F_1 = (0.6 + 0.2 \sin\Theta)(1-M_h C_h)(1-M_m C_m)(1-M_l C_l)$ (Gadd and Keers 1970)

$\simeq (0.6 + 0.2 \sin\Theta)(1-M.CML)$

Mh = 0.4, Mm = 0.7, Ml = 0.7 are the attenuation coefficients and

Ch, Cm, Cl are the fractional amounts of high, medium and low cloud.

The final value for F_1 given above assumes that thin cloud is ignored and that M =0.7; CML is the fractional amount of cloud dense enough to reduce significantly the incident solar radiation.

$F_2 = (1 - N_h C_h - N_m C_m - N_l C_l)$

$\simeq (1 - N. CML)$

$N_h = 0.1$, $N_m = 0.3$, $N_l = 0.6$ are the attenuation coefficients for longwave radiation.

The value N = 0.7 has been assumed in the simplified equation for F_2

FH2B

$$\sin\theta = \sin\delta \sin\phi - \cos\delta \cos\phi \cos\left(\lambda' + \frac{\pi t}{12}\right).$$

where δ, the solar declination, $= 23.5 \cos 2\pi \frac{(d-173)}{365}$

d is the day of the year: 1st Jan = 1 etc.

ϕ is the latitude

λ' is the longitude ($= 0^{\circ}$)

t, time is GMT after integration uses the times of sunrise, t_1, and sunset t_2, from $t_1 = \frac{12}{\pi} \arccos(\tan\delta \tan\phi)$

and $t_2 = 24 - t_1$

Errors due to refraction are insignificant.

The equation was integrated between sunrise and sunset to give a daily total.

$$\int_{t_1}^{t_2} R_{n(h)} = \frac{1-\kappa}{1+\beta} S \int_{t_1}^{t_2} (0.6 + 0.2 \sin\theta)(1-0.7\,CML)\sin\theta \, dt - \int_{t_1}^{t_2} 60(1-0.7\,CML)\, dt$$

$$\int_{t_1}^{t_2} R_{n(h)} = \Big[571.1\,(1-0.7\,CML)(\sin\delta \sin\phi)(t_2 - t_1)$$

$$- 571.1\,(1-0.7\,CML)(\cos\delta \cos\phi \left(\tfrac{12}{\pi}\sin\tfrac{\pi t_2}{12} - \tfrac{12}{\pi}\sin\tfrac{\pi t_1}{12}\right)\Big)$$

$$+ 190.4\,(1-0.7\,CML)(\sin^2\delta \sin^2\phi)(t_2 - t_1)$$

$$- 380.7\,(1-0.7\,CML)(\sin\delta \sin\phi \cos\delta \cos\phi \left(\tfrac{12}{\pi}\sin\tfrac{\pi t_2}{12} - \tfrac{12}{\pi}\sin\tfrac{\pi t_1}{12}\right)\Big)$$

$$+ 190.4\,(1-0.7\,CML)(\cos^2\delta \cos^2\phi \left(\tfrac{1}{2}(t_2 - t_1) + \tfrac{3}{\pi}\sin\tfrac{\pi t_2}{6} - \tfrac{3}{\pi}\sin\tfrac{\pi t_1}{6}\right)\Big)$$

$$- (1-0.7\,CML)(t_2 - t_1) L_o \Big] \; 0.9$$

The 10% reduction in the answer has been included to account roughly for the soil heat flux (G).

The resulting values of (Rn - G) were calculated every fifteen days for cloud amounts 0, 2, 4, 6, 8 oktas and latitudes 50° and 55° North.

Evaporation due to radiation was based on Thom and Oliver's (1977) equation

$$E = \frac{\Delta(Rn - G) + 2.5\,\gamma\,Eap}{\Delta + 2.4\,\gamma} \qquad (2)$$

that caused by radiation is

$$E_R = \frac{\Delta(Rn - G)'}{\Delta + 2.4\gamma}$$

where $(Rn - G)' = (Rn-G)/686$ which gives the evaporation is mm.

Δ is $\frac{\partial e_s}{\partial T} = 4098.025\ e_s /(T + 237.3)^2$ (mb deg C^{-1})

e_s is the saturation vapour pressure = exp(19.0785-4098.025/(T+237.3)) (mb)

T is the temperature (deg C)

γ is the psychrometric constant = 0.66 mb $°C^{-1}$

2. The Aerodynamic Term

From equation (2)

$$E_A = \frac{2.5\ \gamma\ Eap}{\Delta + 2.4\ \gamma}$$

where $Eap = 0.26\ (e_s - e)(1 + \frac{U}{100})$

U the 2 metre wind in miles per day was converted to knots

e the vapour pressure = exp(19.0785 - 4098.025/(Td + 237.3)) mb)

T_d the dew point (°C)

giving $E_A = \frac{2.5(0.66)\left[.26(e_s - e)(1 + .277\ \sigma\ U)\right]}{\Delta + 2.4(0.66)} \left[\frac{t_2 - t_1}{24}\right]$ (mm)

σ = 0.8, the reduction factor applied to the 10m wind.

By selecting values for the various inputs, the nomogram was constructed as shown, with an error on random examples not exceeding 0.25 mm day^{-1}, when compared with direct calculations of evaporation from Thom and Oliver's equation.

Examples are shown in figures 1 and 2.

Any comments or criticisms should be sent direct to the author.

I A Barrie

Meteorological Office

April 1978

REFERENCES

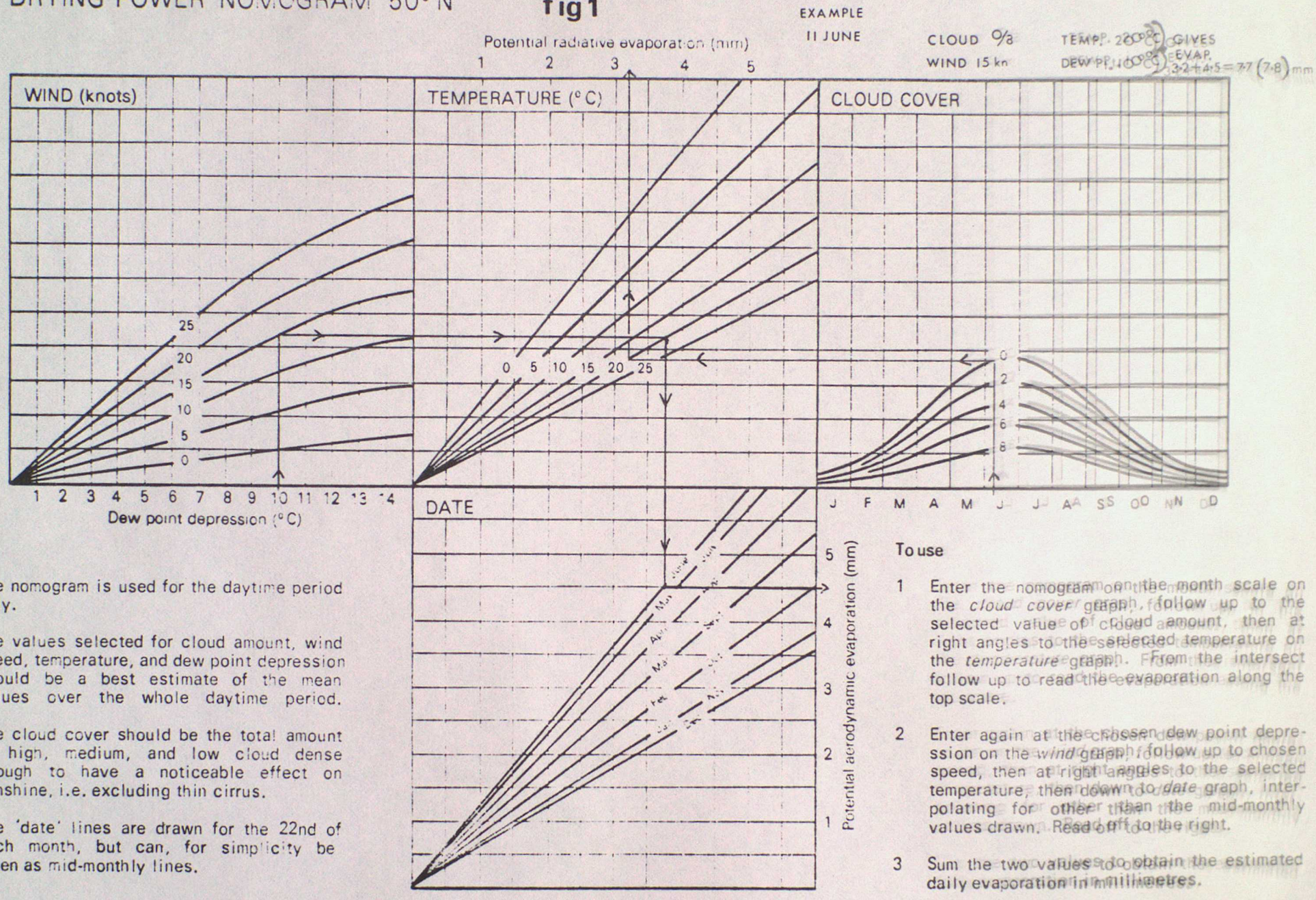
Gadd, A. J. and Keers, J. F. 1970. "Surface exchanges of sensible and latent heat in a 10 - level model atmosphere", Quart, J. R. Met. Soc. 96 p297-308.

Monteith, J. L. and Szeicz, G. 1961 "The radiation balance of bare soil and vegetation". Quart. J. R. Met. Soc. 87 p159-170.

Thom, A. S. and Oliver, H. R. 1977 "On Penmans's equation for estimating regional evaporation". Quart, J. R. Met. Soc. 103 p345-357.

DRYING POWER NOMOGRAM 50° N

fig 1



EXAMPLE
11 JUNE
CLOUD 0/8
WIND 15 kn
TEMP. 20°C
DEW PT. 10°C
GIVES
EVAP.
3·2 + 4·5 = 7·7 (7·8) mm

Notes

1 The nomogram is used for the daytime period only.

2 The values selected for cloud amount, wind speed, temperature, and dew point depression should be a best estimate of the mean values over the whole daytime period.

3 The cloud cover should be the total amount of high, medium, and low cloud dense enough to have a noticeable effect on sunshine, i.e. excluding thin cirrus.

4 The 'date' lines are drawn for the 22nd of each month, but can, for simplicity be taken as mid-monthly lines.

To use

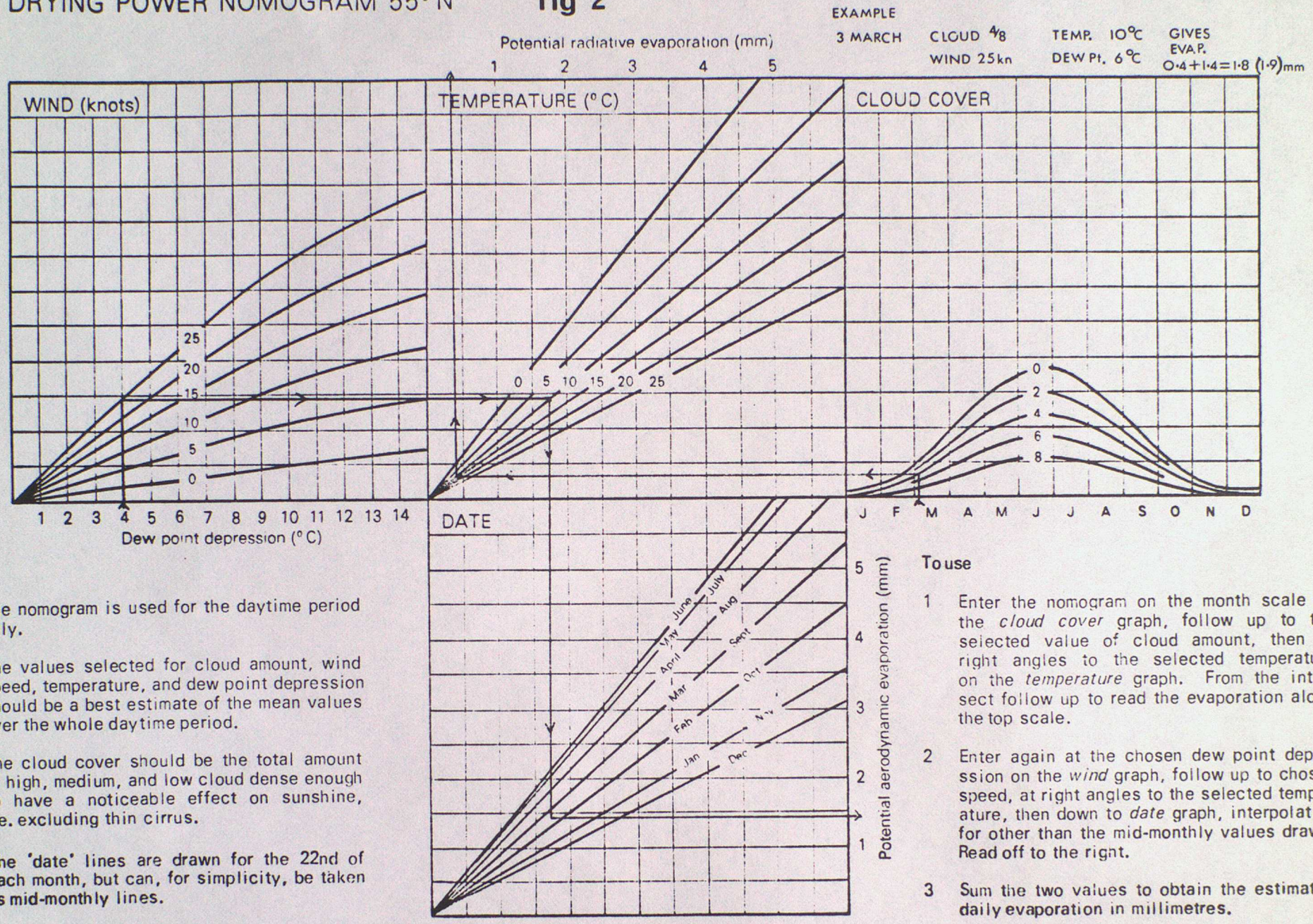
1 Enter the nomogram on the month scale on the *cloud cover* graph, follow up to the selected value of cloud amount, then at right angles to the selected temperature on the *temperature* graph. From the intersect follow up to read the evaporation along the top scale.

2 Enter again at the chosen dew point depression on the *wind* graph, follow up to chosen speed, then at right angles to the selected temperature, then down to *date* graph, interpolating for other than the mid-monthly values drawn. Read off to the right.

3 Sum the two values to obtain the estimated daily evaporation in millimetres.

DRYING POWER NOMOGRAM 55° N

fig 2


EXAMPLE
3 MARCH CLOUD 4/8 WIND 25kn
TEMP. 10°C DEW Pt. 6°C
GIVES EVA.P. 0·4+1·4=1·8 (1·9)mm
Potential radiative evaporation (mm)
1 2 3 4 5
WIND (knots)
25 20 15 10 5 0
1 2 3 4 5 6 7 8 9 10 11 12 13 14
Dew point depression (°C)
TEMPERATURE (°C)
0 5 10 15 20 25
CLOUD COVER
0 2 4 6 8
J F M A M J J A S O N D
DATE
Jan Feb Mar April May June July Aug Sept Oct Nov Dec
5 4 3 2 1
Potential aerodynamic evaporation (mm)

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